DETECTION, LOCATION AND DISCRIMINATION OF SEISMIC EVENTS BY THE SEISMIC NETWORK OF ISRAEL

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ABSTRACT

The Israeli Seismic Network (ISN) consists of 36 short period stations distributed throughout the country. In addition, a Broad Band station is operating at the geophysical observatory near Bar Giyyora, Israel (BGIO) and a small aperture seismic array is under construction in the central Negev desert. The ISN is a regional network which aims to monitor the seismicity in the area bounded by latitudes 27.0N - 36.0N and longitudes 32.0E - 38.0E. It is tuned to detect all seismic events of magnitudes ML>2.0 occurring in Israel. Triggered events are routinely analyzed, yielding a seismological bulletin which provides the seismic event source parameters and classifies the events as earthquakes, explosions, possible explosions and distant events. The detection capabilities of the ISN within Israel is proven to be ML>2.0. In many locations around the country, the threshold magnitude is as low as 0.5. Comparisons of the detection performance of the ISN with those of other international organizations has shown the superiority of the ISN in monitoring the eastern Mediterranean and Middle East regions. Less than 10% of the events detected by the ISN are local and regional earthquakes. Most of the detected events are quarry blasts in Israel, Lebanon and Jordan and detonations associated with infrastructure developments. Sonic wave detectors are used to identify quarry blasts. In parallel, ground truth information is used do develop analytical procedures for discrimination. Presently, the azimuth-invariant, low-frequency spectral modulation method is used to identify the quarry blasts and underwater explosions (UWE) caused by ripple firing and bubbling effects, respectively. Furthermore, spectral ratios of the seismic energy between the low frequency band (1-6 Hz) and the higher band (6-11 Hz) are found useful in discriminating between micro-earthquakes and UWE.

Key Words: detection, location, discrimination, seismic network, spectral discriminants

INTRODUCTION

The Israeli Seismic Network (ISN) was constructed in 1980, starting with analog recording of about 16 stations. Since 1984, data acquisition has been based on computerized systems. At present, the ISN consists of 36 short period stations distributed throughout the country (see Fig. 1). Six stations are equipped with three component seismometers, whereas the rest are vertical component stations. Continuous analog data from the stations are transmitted by FM telemetry to the central recording site at the Institute for Petroleum Research and Geophysics (IPRG) in Holon. There, the data are digitized (50 samples per second) and checked for event detection. Triggered events are routinely analyzed, yielding a seismological bulletin which provides the seismic event source parameters: origin time, hypocenter coordinates, local and body wave magnitudes, seismic moment, stress drop and radius of the rupture area. Earthquake events are classified as earthquakes, explosions, possible explosions or distant events. The ISN has been designed to monitor only the seismicity of the region and, as such, the Israeli Data Acquisition System (ISDA) is tuned to detect all seismic events of magnitude ML>2.0 which occur in and around Israel.

Bulletin information is provided for the area bounded by latitudes 27.0N - 36.0N and longitudes 32.0E - 38.0E. Events which occur outside this area are not usually analyzed, except for measuring their arrival times at the ISN stations. During 1994 a Broad Band station (an STS2 seismometer and a Quanterra data logger) were installed at the Geophysical observatory near Bar Giyyora, Israel (BGIO). This is currently the only long period station in the region. The data are routinely transferred to the GEOFON network center in Germany, which then makes them available worldwide.

During the past few years we began investigating the capabilities of a local seismic microarray. A simplified experimental version of a short-period vertical component seismic microarray was installed on one of the mountains in the Galilee. During the few months of its operation, we have mastered classical data processing techniques using microarray and have developed a new algorithm for interactive analysis based on phase correlation computations. Encouraged by preliminary results, a new microarray is being installed in central Negev desert.

The following paper provides general descriptions of the methods implemented by the IPRG Seismology Division to detect and locate seismic events and to discriminate explosions from earthquakes. Preliminary results from the microarray as well as preliminary estimations concerning the detection capabilities of the ISN are also presented.

DETECTION OF SEISMIC EVENTS

On line event detection is performed by the ISDA system. The algorithm used is, basically, the detection algorithm developed by Johnson (1979) and slightly modified, i.e. weighting the possible contribution of one-sided pulses in STA and LTA computations and rejection criteria for signals which arrive on the same radio frequency. The detection coefficients have been defined by trial and error, comparing the detection performance of the ISDA with identifications made by seismologists on

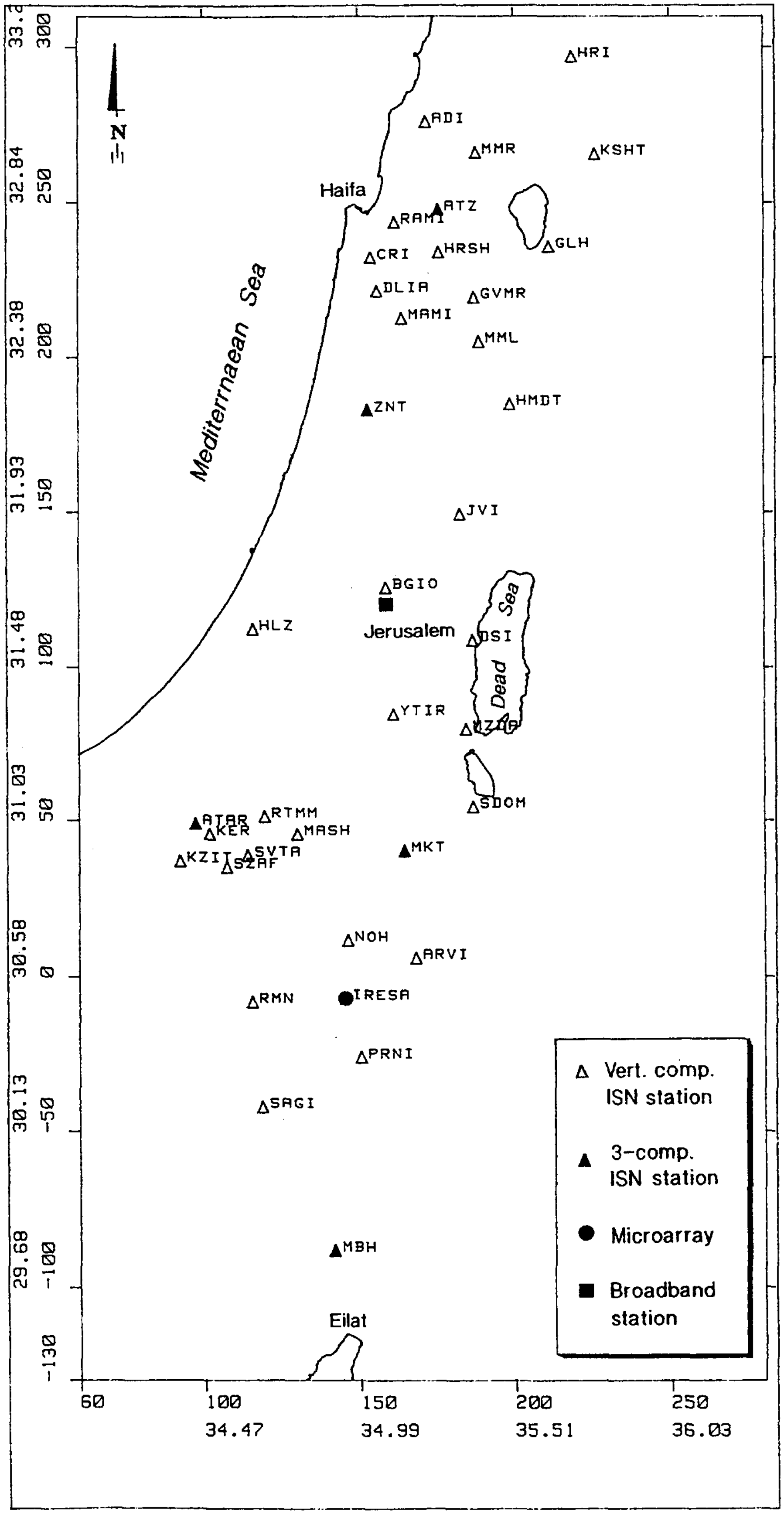

Fig.1 The Israel Seismic Network

continuous analog paper recordings. It has been our aim to ignore small quarry blasts and infrastructure work (which rapidly filled our disks and back-up tapes). Consequently, the ISDA has been tuned to detect only events with magnitudes higher than 1.9 (local scale). Shapira (1992) demonstrated that the detection capabilities of the ISN meet these requirements. It should be noted that in some areas within Israel, either for monitoring a candidate site for a nuclear power plant or for special studies of active faults, a dedicated local network has been installed (usually composed of 6-10 stations) and the magnitude threshold in such cases is much lower; depending on the background noise, it could be $ML \simeq 0.5$.

During the last year, interest in detecting seismic events from outside Israel has increased. The JSOP experiment during September-November, 1994 provided some data for a preliminary assessment of ISN detectability. The JSOP (Joint Seismic Observation Program) has been initiated by the USGS, UNESCO and the Council of Europe (through the EMSC-European Mediterranean Seismological Center) to perform seismic monitoring of the Middle East and eastern Mediterranean regions jointly by the seismological centers of Turkey, Lebanon, Cyprus, Israel, Jordan, Egypt, Saudi Arabia and Yemen. The map in Fig. 2 shows the events reported as $ML>3.0$ by at least one of the participating institutions during the period of the experiment and also events not triggered by the ISDA. Evidently, the detectability of the ISN, within regional distances, is azimuth dependent showing lower sensitivity for events directly north or south of Israel. This azimuthal effect is attributed to the elongated, north-south shape of the network. At present, the ISN is the most sensitive seismic network for detecting and locating events in the Middle East.

Another, qualitative, assessment of the importance of the ISN as regards seismic monitoring in the east Mediterranean and the Middle East is inferred from the comparison between the ISN bulletin and recently reported bulletins of the IDC, Washington and the PDE (NEIC, Colorado). During January - April 1995, of the 68 seismic events of magnitude $ML>2.5$ were reported by the ISN for the region 27.0N - 36.0N and 32.0E - 38.0E, only 56% of them were reported by NEIC and IDC. The detection and location capabilities of the ISN within regional distances are currently being re-evaluated after completion of the JSOP data and unification of the data formats by EMSC.

Beyond this region, the detection capabilities of the ISN have not been fully investigated. One of the major obstacles is the lack of a reference system which should include all events above magnitude 3. Nevertheless, as a first order approximation, using PDE data from NEIC for the period 1990-1994, we have analyzed the statistical distribution of the parameter γ_0 satisfying the condition $\gamma_0 > \gamma_i$, given that for any event i:

$$\gamma_i = \frac{10^{m_b}}{\Delta^2} \qquad (1)$$

where Δ is the angular epicentral distance.

As shown in Fig. 3, the 50% and 90% probability levels are $\log\gamma_0=1.8$ and $\log\gamma_0=3.0$, respectively. However, it should be emphasized that the ISN

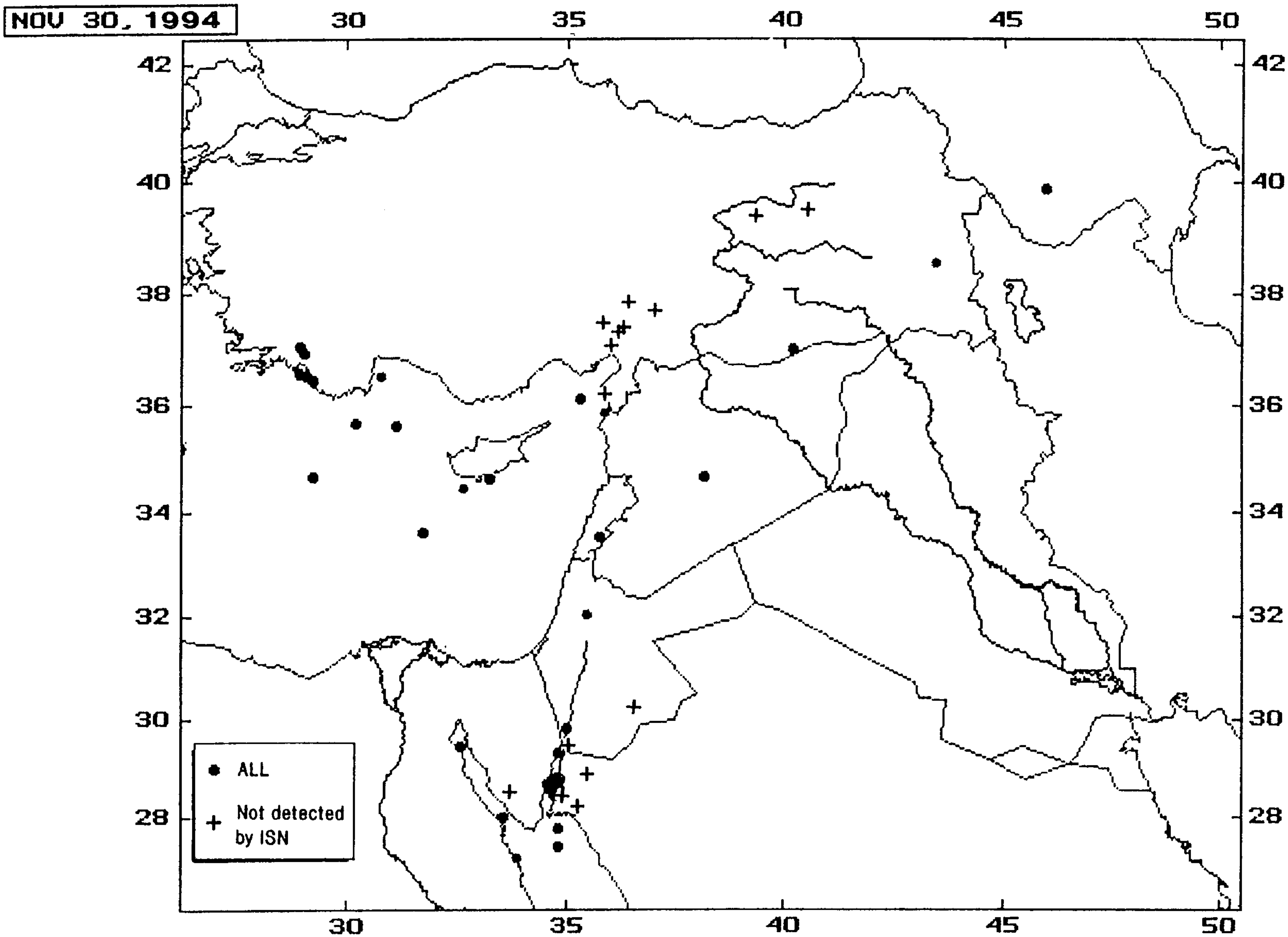

Fig.2 A map of events ($M_L \geq 3.0$) reported during the JSOP experient

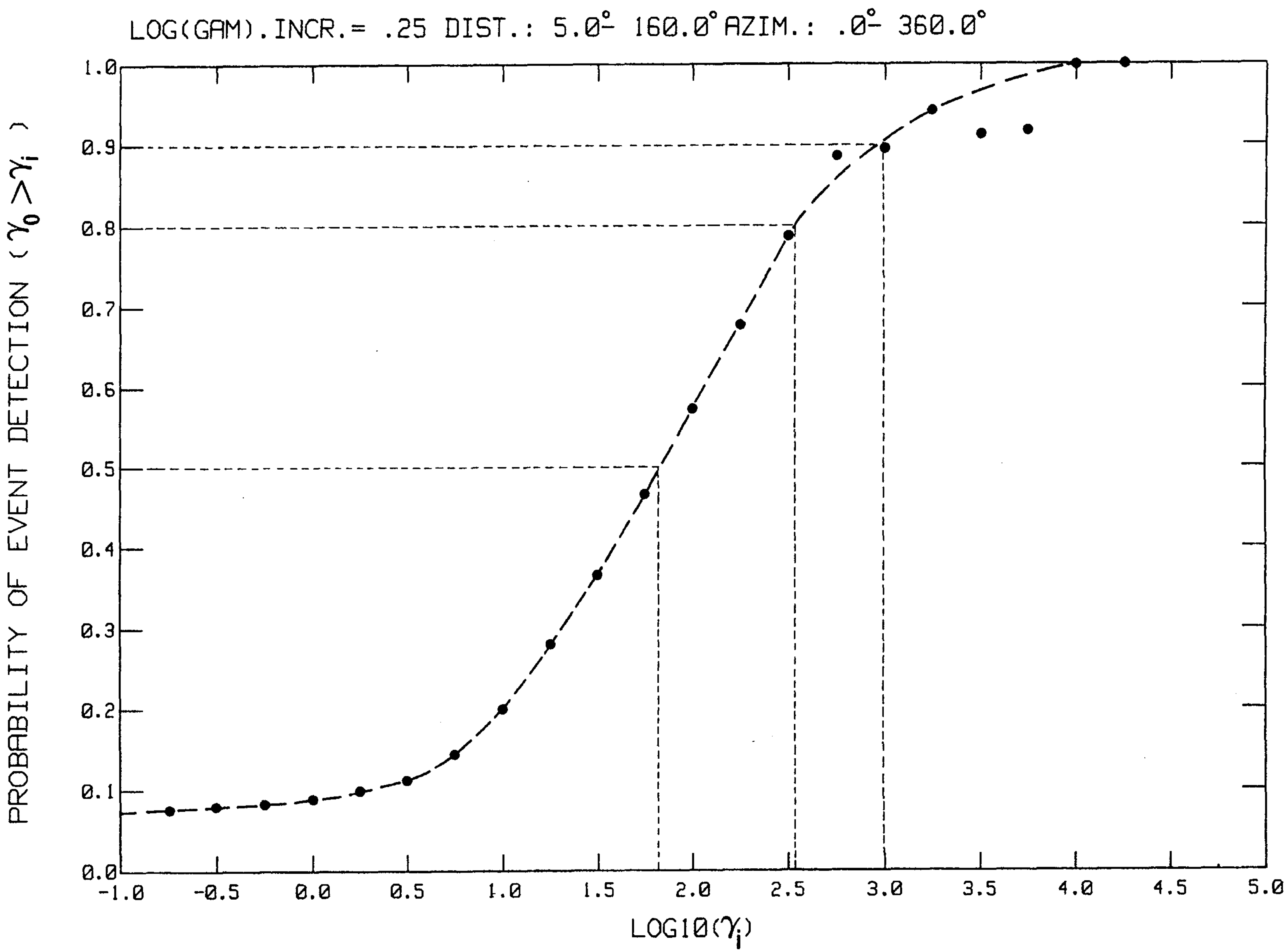

Fig.3 The distribution of a parameter γ

is not currently tuned to detect distant events. With regard to teleseismic distances, the ISN as a system is definitely less sensitive than individual low-noise stations within the ISN. Consequently, the seismic microarray is expected to perform as a much improved detector of events at distances $\Delta>10°$. Although this statement has not yet been tested, it can be judged by comparing the response curve (Fig. 4) of a typical station in the microarray with that of the most sensitive station in the ISN (station PRNI).

LOCATION OF SEISMIC EVENTS.

The location procedure routinely applied by IPRG is based on a search algorithm (Shapira, 1976, 1980). It is a little more time consuming compared with other procedures (e.g. the Geiger method or Simplex procedure), but is much less affected by the multi-minima behavior of the rms time-residual function. Lacking a basis for comparison, it is difficult to estimate the true uncertainty in the mislocation. Shapira and Du Plessis (1989) demonstrated that, in most cases relevant to ISN conditions, the statistical error estimations (i.e. the error ellipsoid) are questionable and not reliable. Comparing location results of quarry blasts in and around Israel, the accuracy in most cases is better than 3 km. (Location accuracies of quarry blasts in Israel are often better than 1 km).

During the recent JSOP experiment, we had the opportunity to compare ISN results with those obtained using data from neighboring countries (i.e. improving the spatial coverage). The differences are in the order of ±15 km. at epicentral distances of several hundred kilometer; however, as expected, ISN mislocations of hypocenters north and south of Israel are much higher. We have also compared ISN results with those provided by IDC and observed that most of the IDC location results in the region covered by the ISN are erroneous.

The small dimensions of the ISN are not suitable for locating distant events from first arrival measurements. To overcome this difficulty, we plan to incorporate the array techniques using the microarray as well as arrays of stations of the ISN in the analysis. Preliminary studies show that classical F-K analysis does not provide sufficiently accurate results and a new concept, based on the interactive process and phase-correlation procedure, is being tested. The new method has been tested on a few events recorded by the microarray and yield very accurate azimuth determinations (accuracy within 1°) and precise detections of the first P and S arrivals. Experiments in this direction will continue.

DISCRIMINATION OF SEISMIC EVENTS

Less than 10% of the events detected by the ISN are local and regional earthquakes. Most of the detected events are quarry blasts in Israel, Lebanon and Jordan and detonations associated with infrastructure developments. Ground true information from Israeli quarries is routinely collected and is used to verify location results and identifications made by the analysts. In the last year, sonic wave detectors have been installed at some of the ISN stations. The detector is merely a loudspeaker mounted in a resonance box. Many of the man-made events are detected by the loudspeakers, which are used to classify the event as an

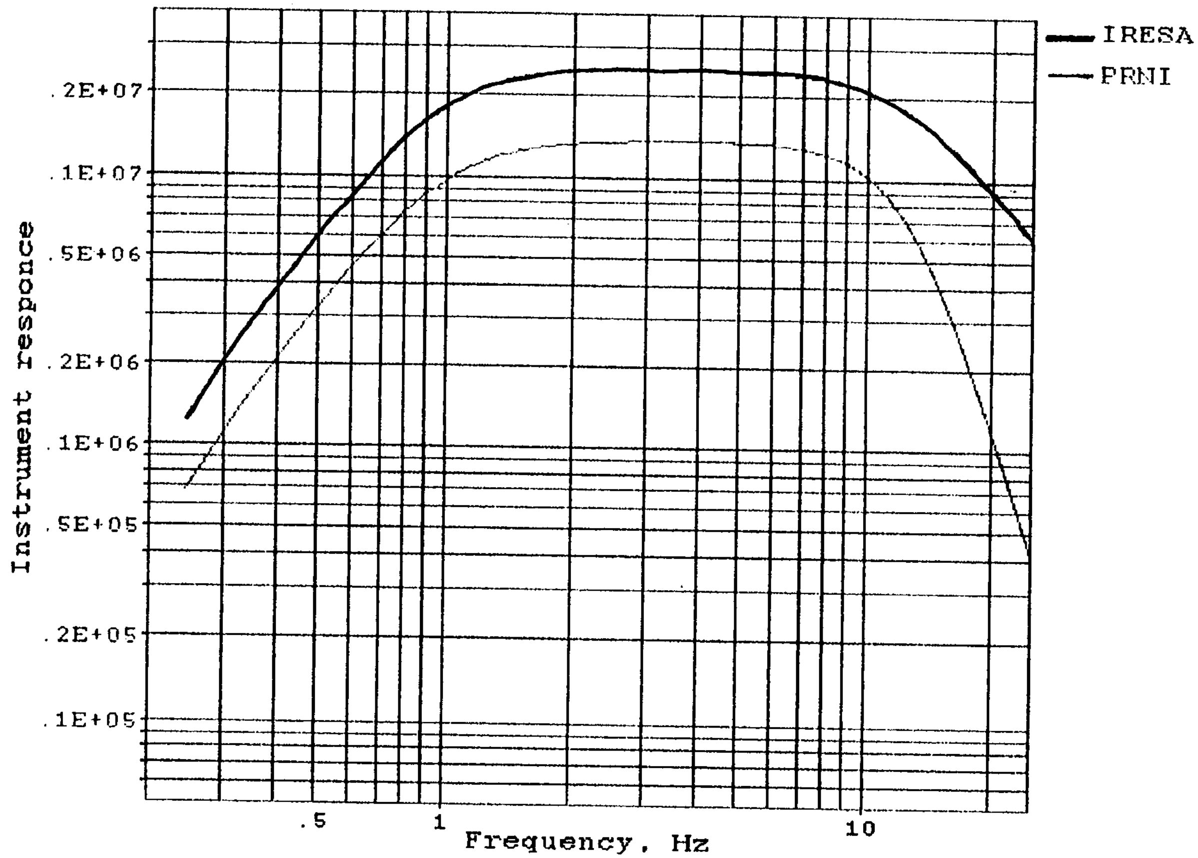

Fig.4 Response curves of the typical station in the microarray and station PRNI (most sensitive station in the ISN)

explosion. This technique is most useful in places where the source is within 40 km of the detector, mainly owing to the fact that the ISDA will trigger only additional 120 sec after the last trigger time.

Analytical discriminators for ISN operations have been tested by Gitterman and van Eck (1993) and by Gitterman and Shapira (1994). The azimuth-invariant, low-frequency spectral modulation (LFSM) method is used to identified the quarry blasts and underwater explosions (UWE) caused by ripple firing and bubbling effects, respectively. Strongly smoothed spectra yield coherent maxima and especially minima in the spectra at different stations, in accordance with the interference phenomenon of the reverberating or ripple firing source. Gitterman and Shapira (1993) also show that spectral ratios of the seismic energy between the low frequency band (1-6 Hz) and the higher band (6-11 Hz) are useful in discriminating between micro-earthquakes and UWE.

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